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Abstract:
With a view to determine the effectiveness of the policies aimed at boosting natural gas consumption, this paper examines the unit root properties of natural gas in 44 countries, for the period 1965 to 2010. Applying the LM unit root tests, which allow for a maximum of two structural breaks, we are able to reject the null hypothesis of unit root in the natural gas consumption series in 57% of the countries. A key policy implication of this finding is that initiatives designed to have permanent positive effects on natural gas, such as construction of large natural gas pipeline network, are likely to be effective in increasing the share of natural gas consumption in only 43% of the total sample.

Keywords: Gas Consumption, Stationary, Structural Breaks

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I. Introduction

Natural gas is a major important source of non-renewable energy and is seen as an alternative to reducing the dependence on oil at a time when oil reserves are drastically depleting around the world economy. Besides, natural gas is seen to have clear merit as a cleaner alternative to other fossil fuels and as a viable means of energy for countries to meet the energy demands (Golpe et al., 2012). The literature on energy demand mostly seems to provide the empirical evidence in support of the stationarity properties of energy consumption. Several studies in this literature have tested for unit root in several forms of energy consumption. For instance, Lee and Chang (2005), Al-Irani (2006), Chen and Lee (2007), Narayan and Smyth (2007), Hsu et al. (2008), Lean and Smyth (2009), Mishra et al. (2009), Apergis et al. (2010a, b), Narayan et al. (2010), Ozturk and Aslan (2011), Hasanov and Telatar (2011), Aslan (2011), Aslan and Kum (2011), Kula et al. (2012), Shahbaz et al. (2013, 2014), Lean and Smyth, (2014a, b) and Solarin (2015) applied a varieties of unit root testing procedures to examine the stationarity properties of various forms of energy consumption.

There are studies that have specifically focussed on the unit root properties of natural gas consumption. Many of these studies have also found non-stationarity in natural gas consumption. For instance, Lean and Smyth (2014a) employed the Lee and Strazicich (2003) test on annual natural gas data for Malaysia and concluded that natural gas consumption contained a unit root. Aslan (2011) applied the Lee and Strazicich (2003) test and the Kapetanios et al. (2003) non-linear unit root test to annual natural gas data for 50 states in U.S. The results provided evidence for non-stationary for majority of the states. Gil-Alana et al. (2010) used fractional integration tests on natural gas consumption by the power sector in U.S and it yielded highly persistent results. Using a non-linear unobserved components model, Golpe et al. (2012) found evidence of hysteresis in natural gas consumption in the U.S. There is also evidence for stationarity of natural gas consumption. Apergis et al. (2010b) used the panel unit root tests with structural breaks on natural gas consumption in 50 states of U.S and found natural gas consumption to be panel stationary. In sum, there are mixed findings in the natural gas consumption studies, although several papers observed a non-stationarity with respect to natural gas consumption. The mixed findings of unit roots from the previous empirical investigations motivate us to check whether the shocks to natural gas consumption have temporary or persistent effects.

The issue of whether gas consumption per capita contains a unit root is important for several reasons. If the gas consumption per capita is stationary, shocks will be transitory and the per capita gas consumption would return to its long-run level. If gas consumption follows stationary process then the long-run energy policies would not be effective which may rather indicate the inelasticity in its consumption demand. Natural gas consumption would tend to return to its original path following shocks in the energy markets. On the other hand, if the series is found to be non-stationary, shocks will have permanent effects and it would diverge from its long run level. Furthermore, to the extent that per capita natural gas consumption is closely linked with other real sectors of the economy, the unit root generated by a nonstationary natural gas will be transmitted to the economy. The persistence would also have important implication for forecasting and modelling energy demand. If it is stationary, this implies that it is possible to forecast the future per capita gas consumption requirements for economies, but the same is not possible to forecast, if it contains a unit root.

With the exception of Aslan (2011), Apergis et al. (2010b) and Golpe et al. (2012), which have all focussed on the U.S. economy, the studies in the literature do not examine the unit root properties of gas consumption, despite its importance as an energy source and the need to grasp the likely efficacy of the policies to increase the proportion of gas in electricity mix. The evidence provided by the existing energy economics literature is mixed. Besides, there is no study that has ventured into the examination of the stationarity properties of natural gas consumption on a multi-country basis. The aim of the current exercise is to examine the unit root properties in natural gas consumption for 44 countries over the period 1965-2010. We address a gap in the existing energy economics literature by not only considering the unit root properties of natural gas consumption in the U.S, but also in several countries, as well.

II. Methodology and data

The traditional unit root tests like Augmented Dickey Fuller, (1979), Phillips–Perron (1988) and Perron (1990) are found to be biased towards the non-rejection of null hypothesis in presence of structural breaks in a series. Following these tests in the literature, Zivot and Andrews (1992) tried to determine the stationarity properties of economic variables by endogenously capturing the structural breaks stemming from the series. Lumsdaine and Papell (1997) discovered the importance of unit root test with two structural breaks in the series by modifying Zivot and Andrews (1992) unit root test. Nevertheless, these advancements were criticized by the statisticians due to the fact that these tests do not consider the presence of structural breaks in the null hypothesis except suggesting that variables are found to be stationary in the presence of structural breaks. Therefore, the present study employs the unit root procedure advanced by Lee and Strazicich (2003, 2004) to overcome such drawbacks and this allows us to test for at most two endogenous breaks using the Lagrange Multiplier (LM) test statistics. The LM unit root test with two breaks developed by Lee and Strazicich (2003) represents a methodological improvement over the Dickey-Fuller-type endogenous two break unit root test proposed by Lumsdaine and Papell (1997). This test has better size and higher power, and that it identifies the structural breaks more accurately, than the test proposed by Lumsdaine and Papell (1997). By taking account of the structural breaks in the per capita gas consumption series would significantly increase the power of the unit root tests and more significant results may be obtained from the present analyses. Our results are expected to be more reliable and efficient due to the superiority of Lee and Strazicich (2003, 2004) unit root test over the traditional unit root tests. This test stands out as a superior procedure as it provides for structural breaks under both the null and alternative hypotheses. Allowing for the breaks under the null hypothesis is necessary in order to circumvent spurious rejections and invalid results (Lee and Strazicich, 2001). The test proceeds as follows:

$$\Delta S_t = \delta' \Delta Z_t + \phi \bar{S}_{t-1} + \sum_{i=1}^{p} \gamma \Delta \bar{S}_{t-i} + \mu_t \qquad (1)$$

Here, Δ is the difference operator, while $\bar{S}_{t-i}$ is the detrended value of S_{t-i}. The null of unit root, $\phi = 0$ is tested against the alternative hypothesis $\phi < 0$. Structural break is incorporated into the model with Z_t, which is a vector of exogenous variables. In a specification that allows for a single change in both level and trend, $Z_t = [1, t, D_{1t}, DT_{1t}]'$ where $DT_{1t} = t$ if $t \geq T_B + 1$, and 0, otherwise. D_{1t} and DT_{1t} are the dummy variables that denote the time when a structural break occurs in the level and trend respectively. To endogenously determine the location of $\lambda_j = T_{Bj} / T, j = 1$, the "minimum LM test" in Lee and Strazicich (2004) is used. In a specification that provides for two changes in both level and trend, $Z_t = [1, t, D_{1t}, D_{2t,} DT_{1t}, DT_{2t}]'$ where $DT_{jt} = t$ if $t \geq T_{Bj} + 1, j = 1,2$ and 0, otherwise. In this study, augmented terms of $\Delta \bar{S}_{t-i}$ are introduced to ensure there are no serial correlations in the errors.[1]

III. Empirical Findings

The two-break LM unit root test results of gas consumption per capita for the sampled 44 countries are reported in Table-1 (Algeria, Argentina, Australia, Austria, Bangladesh, Belgium, Luxembourg, Brazil, Bulgaria, Canada, Chile, China, Colombia, Czech Republic, Ecuador, Egypt, France, Germany, Hungary, India, Indonesia, Iran, Italy, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Pakistan, Peru, Poland, Qatar, Romania, Saudi Arabia, Slovakia, Spain, Switzerland, Taiwan, Thailand, Trinidad and Tobago, UAE, UK, US and Venezuela). The study covers the period of 1965-2010. The data for natural gas consumption is collected from *BP Statistical Review of World Energy* (http://www.bp.com). The null hypothesis can be rejected in 25 countries or 57% of the total sample, with eleven countries at 1% significance level, another nine countries at 5% significance level and the remaining five countries at 10% significance level. These results indicate that fluctuations in natural gas consumption per capita in these countries are temporary. In other words, random shocks to gas consumption may lead to temporary deviations from predetermined target levels. In this case, any programme or initiative to enhance the natural gas consumption in the countries may have little impact on this form of energy as well as employment and output (Smyth, 2013)[2]. On the other hand, null hypothesis cannot be rejected in 19 countries or 43% of the total countries in our study. This implies that energy policies and blueprints will have long-term permanent impact on

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[1] To determine the lag length of k we follow the process recommended by Campbell and Perron (1991) and Ng and Perron (1995). Starting with an upper bound k_{max} on k, $k = k_{\max}$ is chosen if the existing lag is significant. If not, k is reduced by a unit until the lag is significant. If none of the lags are significant, then $k = 0$. In the empirical section, we set $k_{\max} = 8$ and use the 10% value of the asymptotic normal distribution, 1.645, to determine the significance of the last lag.

[2] We differ from Smyth (2013) in this case who argues that the policy implication should be reduction in fossil fuels, which natural gas is a component. In practice, natural gas is being promoted as a substitute for other forms of fossil fuels such as coal.

natural gas consumption per capita. In sum, these results provide mixed evidence for stationarity of natural gas consumption per capita but consistent with Aslan (2011) and Apergis et al (2010) who established mixed findings for the U.S. Looking at the structural breaks in Table-1, we observe a total of 77 breaks, with 33 countries experiencing double breaks, while 11 countries generating single structural break. The findings show that 28 breaks or 36% of the total breaks clusters around the late 1970s cum the early 1980s, which was a period of significant changes in the global energy outlook. These incidents include energy crisis of 1979 that was triggered by the Iranian revolution and adversely affected the country's energy sector and global energy industry[3]. Besides, the world experienced the oil glut (caused by falling demand) in the early 1980s plus the outbreak of Iran-Iraq war (in September, 1980), which severely affected the global energy outlook (Hamilton, 2011; Noguera, 2013).

Table-1: LM unit root test with two structural breaks

Test	Lee and Strazicich test				
Country	T_{B1}	T_{B2}	T-Stat	*k*	Break point(s)
Algeria	1991		-3.39	7	-0.6
Argentina	1991		-4.80**	4	-0.6
Australia	1980		-1.54	0	-0.4
Austria	1984	1991	-4.18	7	(0.4, 0.6)
Bangladesh	1999		-4.24*	8	-0.8
Belgium Luxembourg	1989	1995	-3.94	6	(0.4, 0.6)
Brazil	1987	2000	-6.31**	6	(0.6, 0.8)
Bulgaria	1980	1986	-9.17***	1	(0.4, 0.6)
Canada	1989	1997	-4.21	7	(0.6, 0.8)
Chile	1986	2005	-6.14**	5	(0.6, 0.8)
China	1989		-4.24*	7	-0.6
Colombia	1979	2005	-5.1	7	(0.4, 0.8)
Czech	1979	1995	-4.97	4	(0.4, 0.6)
Ecuador	1987		-4.90**	3	(0.6)
Egypt	1982	1987	-6.33***	7	(0.4, 0.6)
France	1980	1995	-4.34	8	(0.4, 0.6)
Germany	1987		-2.37	5	(0.6)
Hungary	1978		-3.1	2	(0.4)
India	1979	1999	-4.812	6	(0.4, 0.8)
Indonesia	1982	1999	-6.48***	3	(0.4, 0.8)
Iran	1978	1986	-8.03***	6	(0.2, 0.4)
Italy	1980	2001	-6.08**	8	(0.4, 0.8)
Japan	1982	1987	-5.12	8	(0.4, 0.8)
Kuwait	1990	1997	-6.28**	7	(0.6, 0.8)

[3] More than half of the world's gas reserves are in three countries: Russia, Iran and Qatar (OPEC, 2010).

Malaysia	1983	1999	-7.73***	3	(0.4, 0.8)
Mexico	1979	1995	-5.73**	6	(0.4, 0.6)
Netherlands	1986	1996	-5.42*	8	(0.4, 0.8)
New Zealand	1981	1988	-5.87**	8	(0.4, 0.6)
Pakistan	1980	2001	-5.55*	8	(0.4, 0.8)
Peru	1981	1995	-6.46	7	(0.4, 0.6)
Poland	1980	1987	-3.04	7	(0.4, 0.6)
Qatar	1980	1997	-6.00**	7	(0.4, 0.8)
Romania	2005		-2.48	7	(0.8)
Saudi	1982	1994	-6.62***	6	(0.4, 0.6)
Slovakia	1981		-2.38	6	(0.4)
Spain	1982	2000	-4.38	5	(0.4, 0.8)
Switzerland	1980	1995	-15.744***	3	(0.4, 0.6)
Taiwan	1980	1995	-4.78	8	(0.4, 0.6)
Thailand	1979	1990	-8.82***	8	(0.4, 0.6)
Trinidad	1984	2003	-7.54***	6	(0.4, 0.8)
UAE	1989		-5.36***	1	(0.6)
UK	1986	1998	-2.372	8	(0.4, 0.8)
US	1980	1993	-6.97***	5	(0.4, 0.6)
Venezuela	1991	1997	-5.41*	6	(0.6, 0.8)

Critical values for Lee and Strazicich (2003)

Y	0.4			0.6			0.8		
	10%	5%	1%	10%	5%	1%	10%	5%	1%
0.2	-5.27	-5.59	-6.16	-5.32	-5.74	-6.41	-5.33	-5.71	-6.33
0.4	-	-	-	-5.31	-5.67	-6.45	-5.32	-5.65	-6.42
0.6	-	-	-	-	-	-	-5.32	-5.73	-6.32

T_B is the estimated break points. *, ** and *** imply 1%, 5% and 10% levels of significance. Critical values in the lower panel of Table 3 are from Lee and Strazicich (2003), while the critical values for Lee and Strazicich (2004), one break tests are -5.05, -4.50 and -4.18 for at the 1, 5 and 10 % levels of significance.

IV. Concluding Remarks and Future Directions

This paper investigated the unit root properties of natural gas consumption per capita by applying LM unit root test with two structural breaks and using the data of 44 countries. The study used the period of 1965-2010. Our empirical evidence provides mixed results on unit root hypothesis. In 57% of sampled countries, the null hypothesis of unit root hypothesis is rejected. This implies that variations in natural gas consumption per capita are transitory in these countries and as such policy initiatives to enhance the use of natural gas consumption will not be effective. The null hypothesis of unit root problem is rejected in 43% of sample countries. This entails that fluctuations in natural gas consumption per capita are permanent and as such policy initiatives to increase the use of natural gas consumption will be effective.

The method applied in this study- Lee and Strazicich, (2003, 2004) are not free from criticisms. Although providing for structural breaks enhances the power of the conventional unit root tests, deploying dummies to approximate breaks has several undesirable consequences. For instance, when the break dates are *a priori* unknown, it is helpful to acquire some information concerning the absence or presence of a change in the process of examining the possible presence of a unit root. Furthermore, cyclical behaviour of most macroeconomic series including natural gas consumption is best characterised by nonlinear functional form. This is because the movement between the peak and trough periods are gradual and not instantaneous and therefore are better captured by a nonlinear model than a linear model with structural breaks (Beechey and Österholm, 2008; Solarin, 2014). Therefore, future studies may apply nonlinearity techniques to examine the stationarity of natural gas consumption in these countries.

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